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6. AUTHOR(S)

Alan S. Gevins, PI
Harrison Leong

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

EEG Systems Laboratory
51 Federal Street, Suite 401
San Francisco, CA 94107

8. PERFORMING ORGANIZATION REPORT NUMBER

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USAF, AFSC
Air Force Office of Scientific Research
Bldg. 410
Bolling AFB, DC 20332-6448
Dr. Tangney

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13. ABSTRACT *(Maximum 200 words)*

We made progress in several areas during the past year: 1) tested the Neurotrigger hardware/software system and moved it onto a new platform for increased number of channels and a needed increase in computational headroom; 2) performed pilot recordings seeking simpler EEG measures of focused attention associated with heightened ability to receive and retain information; 3) implemented filters to remove signal contaminants typically generated by stationary subjects doing laboratory tasks, specifically eye blinks, eye movements, and muscle tension on the head; 4) designed, implemented, and piloted a new task for training the production of a preparatory attentive state associated with heightened ability to receive and retain information. We also revised a manuscript on a prior AFOSR-sponsored study of working memory; the manuscript has been accepted for publication. We also completed statistical analyses and figures and nearly completed a manuscript on a prior AFOSR-sponsored experiment on the neurophysiology of language.

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NEURO TRIGGERED TRAINING

AFOSR Contract F49620-90-C-0026

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1 APR 92 to 31 MAR 93

PREPARED FOR

Dr. John Tangney
Directorate of Life Sciences
Air Force Office of Scientific Research
Bolling AFB, D.C. 20332-6448

APPROVED BY

Alan Gevins, Director

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PERSONNEL

Alan Gevins, Principal Investigator
Harrison Leong, Neuroengineer
Michael Smith, Neuroscientist
James Johnston, Biophysicist
Bill O'Connor, Programmer
Jeffrey Bennett, Research Associate
Paul Brickett, Psychophysiologist (memory and language manuscripts)
Brian Cutillo, Cognitive Scientist (memory and language manuscripts)

PUBLICATIONS IN THE PAST YEAR

Gevins, A.S. and Cutillo, B.C. (In press, 1993) Neuroelectric evidence for distributed processing in human working memory. *EEG Clin. Neurophysiol.*

J. Le & A.S. Gevins (In press, 1993) Mothod to reduce blur distortion from EEGs using a realistic head model. *IEEE Transactions on Biomedical Engineering.*

Gevins, A.S. (In press, 1993) High resolution evoked potentials of cognition. *Brain Topography.*

Gevins, A.S., et al. (Submitted, 1993) Imaging the spatiotempral dynamics of cognition with high resolution evoked potential methods. *Human Brain Mapping.*

Gevins, A.S., et al. (In press, 1993) High resolution EEG: 124-channel recording, spatial enhancement and MRI integration methods. *EEG Clin. Neurophysiol.*

Gevins, A.S., et al. (In Press, 1993) High resolution evoked potential technology for imaging neural networks of cognition. In: Thatcher, R.W., et al. (Eds.) *Functional Neuroimaging: Technical Foundations.* Academic Press, Inc. : Orlando.

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Wikswo J.P., Gevins, A.S., Williamson S. J. (In press) The future of the EEG and MEG. *EEG Clin. Neurophysiol.*

Gevins, A.S., et al. (1992) The future of high-resolution EEGs in assessing Neurocognitive effects of mild head injury. In: D. Katz & M. Alexander (Eds), *Journal of Head Trauma Rehabil., 7(2),* pp. 78-90.

NEURO-TRIGGERED TRAINING (TRIGGER)

The objective of the Trigger project is to determine the feasibility of a method to accelerate the learning of a simple cognitive task and to optimize performance by delivering stimuli at instants when preparatory attentional cortical networks are optimally activated. We plan to achieve this objective by determining the prestimulus EEG patterns associated with a subject's accurate task performance using neural-network pattern recognition, and then training the subject to produce those patterns on a single-trial basis.

Personnel Changes

Brian Cutillo, previously Co-PI, is no longer involved with the project. Harrison Leong, a neuroengineer who is experienced in neural network pattern recognition, is now managing the day-to-day conduct of the project. Michael Smith, a cognitive neuroscientist specializing in the neuropsychology and neurophysiology of memory and attention, is working on task and experimental design and data analysis. The programming is being performed by Jim Johnston and Bill O'Connor who are both experienced in PC programming. Johnston is additionally an expert on EEG feedback systems. Jeffrey Bennett is assisting with data collection and analysis.

System Development

The first Neurotrigger system we implemented was based on commercial software and hardware including the EEGSYS program, Labmaster digitizer, and Beckman amplifiers. Running on a 33 MHz PC486, the system was benchmarked to determine processor time available for real time signal analysis after handling electrophysiological data collection and task stimulus presentation. Headroom was less than 0.25 Mflops. This was deemed insufficient for real time artifacting and other signal processing needed for neurotriggering. At this juncture, an electrophysiological data collection system (SMARTHAT) being developed by our sister organization, SAM Technology, was far enough along so that it was most cost effective to obtain the computational headroom we needed by modifying a SMARTHAT system to perform neurotriggering. Benchmarks indicate it yields approximately 2.25 Mflops of computational headroom; this will suffice for the artifact minimization and signal processing we will require. (A further increase in computational headroom can easily be obtained by changing the processor to a 66 MHz PC486.) Additional benefits include higher noise immunity due to on-the-head pre-amplification, simplified usage by obviating the need to prepare the scalp at each electrode site, more EEG channels (up to 32), and high level inputs for sources such as response transducers and accelerometers for use in detecting and minimizing head movement artifact. SMARTHAT also provides a library of software functions that can be used to express a wide variety of tasks with little concern for how to make the tasks run simultaneously with electrophysiological data collection.

The feasibility of using this system for the Neurotrigger project was verified. A simple CNV task was programmed (visual cue followed by a stimulus that required right or left hand response) and used as a final test of the system. Averages were computed and CNVs were observed where expected.

Real-time Artifact Processing

Algorithms for minimizing EEG contamination caused by eye movements and blinks and muscle tension were developed at SAM Technology and are being made available for this project. These contaminants are those most likely to compromise the accuracy of neurotriggering in controlled conditions where the subject is stationary and doing laboratory tasks designed to minimize sources of EEG contamination. The algorithms were designed for use in real-time and were rapidly developed using MATLAB from Mathworks, Inc. The next step is to translate MATLAB code into C and/or assembly language, integrate this software with the SMARTHAT software, and test.

Pilot Recordings

A series of recordings with a variety of task variations were made to find a simple EEG signal of heightened, focused attention. Following the lead of previous research (reviewed in Gevins and Schaffer, 1980), we sought a reliable diminution of alpha power and enhanced theta power with the onset of focused attention. In one task, subjects were instructed to try to mentally move a cursor by sharply focusing their attention on it; the cursor remained stationary. In a similar task, the cursor was programmed to move in such a way that it appeared to be under neurotriggered control. Although we did observe expected changes in alpha and theta power, we concluded that more than a second of data would be needed to reliably detect changes in these parameters. In particular, we observed that the amplitude, duration, and frequency of alpha bursts decreased when the subject's attention was narrowly focused; but, there was no clear, reliable abrupt change in alpha within ±0.5 seconds of when the onset of this mental state was to occur. The time scale for reliable detection would be too long for neurotriggering, which requires a decision in about 500 msec. Hence, we decided it would be most fruitful to focus our efforts on finding single-trial CNV features that characterize optimal states of preparatory attention.

Improvements to the Experimental Approach

We have improved our approach by opting for training a preparatory attentional state that is more cognitively loaded than motor priming. Specifically, we plan to focus on training the ability to produce a heightened state of concentration to receive and retain information. In addition, we will provide feedback training that better adapts to the subject's immediate needs by using continuously graded neurotriggering instead of binary triggering: Instead of waiting for the subject to produce a "correct" neuroelectric pattern before giving a stimulus, the quality of the stimulus will be modulated based on the degree to which the subject produces optimal neuroelectric patterns and, furthermore, stimulus quality will be a factor in the overall measure of performance upon which a monetary bonus will be computed. We will use the Sternberg memory scanning task (Sternberg, 1966) in which a set of letters to be remembered is briefly presented, followed by probes that test retention of this information. The task has a known CNV to the set of letters which has been observed to be predictive of performance accuracy (Morgan et al., 1992). The duration of the memory set will be modulated based on an electrophysiologic assessment of the degree to which the subject is prepared to receive and absorb the information presented. The maximum task performance level achieved and the time required to achieve this level will be measured. These measures will be compared with those achieved when training is based on modulating the letter set duration using behavioral performance or randomly. Separate groups of subjects will be used for each condition. Subjects will be carefully selected for equivalent initial performance on the task and percent change in performance will be used to compare the effects of each condition. This experiment permits us to observe, in one example, the value of instantaneous adaptation of stimulus presentation (neurotriggering) compared to adapting over a longer time frame (adaptation based on behavioral data only) and no adaptation to subject state. It may be necessary to increase the difficulty of the task so that the training effects are large enough. Variations of the task that are cognitively more difficult can be simply constructed by changing the information that must be retained and the way retention is tested; for example, paired associates can be used in place of letters.

Next Steps

1) Gather more pilot data and complete analysis of this data to determine single trial CNV signal features that will be used for neurotriggering;

2) Enhance system software to perform real-time artifact contaminant minimization and, we anticipate, estimate regional single-trial CNV amplitude relative to a baseline.

3) Modify the Sternberg task implementation to provide adaptive control of its stimulus parameters (memory set duration) by control signals derived from electrophysiological data or behavioral data.

4) Test the fully implemented system and pilot the three training conditions.

5) Modify the system and task as necessary, i.e. increase task difficulty.

6) Obtain and analyze recordings from six subjects.

PUBLICATION OF RESULTS OF WORKING MEMORY STUDY

A paper describing the results of a prior AFOSR-sponsored pilot study on working memory has been accepted for publication in The EEG Journal.

MANUSCRIPT OF RESULTS OF LANGUAGE STUDY

We also completed statistical analyses and figures and nearly completed a manuscript on a prior AFOSR-sponsored experiment on the neurophysiology of language. The manuscript will shortly be submitted to The EEG Journal.

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